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Selby

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(54) **VARIABLE STATOR VANE ACTUATING LEVERS**

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(51) **Int. Cl.**
F01D 17/16 (2006.01)

(52) **U.S. Cl.** **415/156**; 415/160; 415/162; 74/519; 403/154; 403/155

(58) **Field of Classification Search** 415/119, 415/156, 159–166; 74/519; 403/150, 154, 403/155; 267/158, 160, 173, 174
See application file for complete search history.

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(57) **ABSTRACT**

A variable stator vane actuating lever (**50**) for use in a compressor (**20**) of a gas turbine engine (**10**). The lever (**50**) comprises a first end (**52**) for pivotal connection to a stator vane actuator ring (**36**) and a second end (**54**) for abutting a stator vane spindle (**32**). The stator vane spindle (**32**) has a diameter and flat positions (**56**,**58**,**60**,**62**). The second end (**54**) of the lever (**50**) has resilient members (**64**,**66**) for abutting the flat portions (**56**,**58**,**60**,**62**) of the stator vane spindle (**32**) at diametrically opposite locations. The resilient members (**64**,**66**) are integral with the second end (**54**) of the stator vane spindle (**32**) and are curved so that they are substantially tubular to provide even load distribution and improved location of the lever (**50**) on the stator vane spindle (**32**).

18 Claims, 4 Drawing Sheets

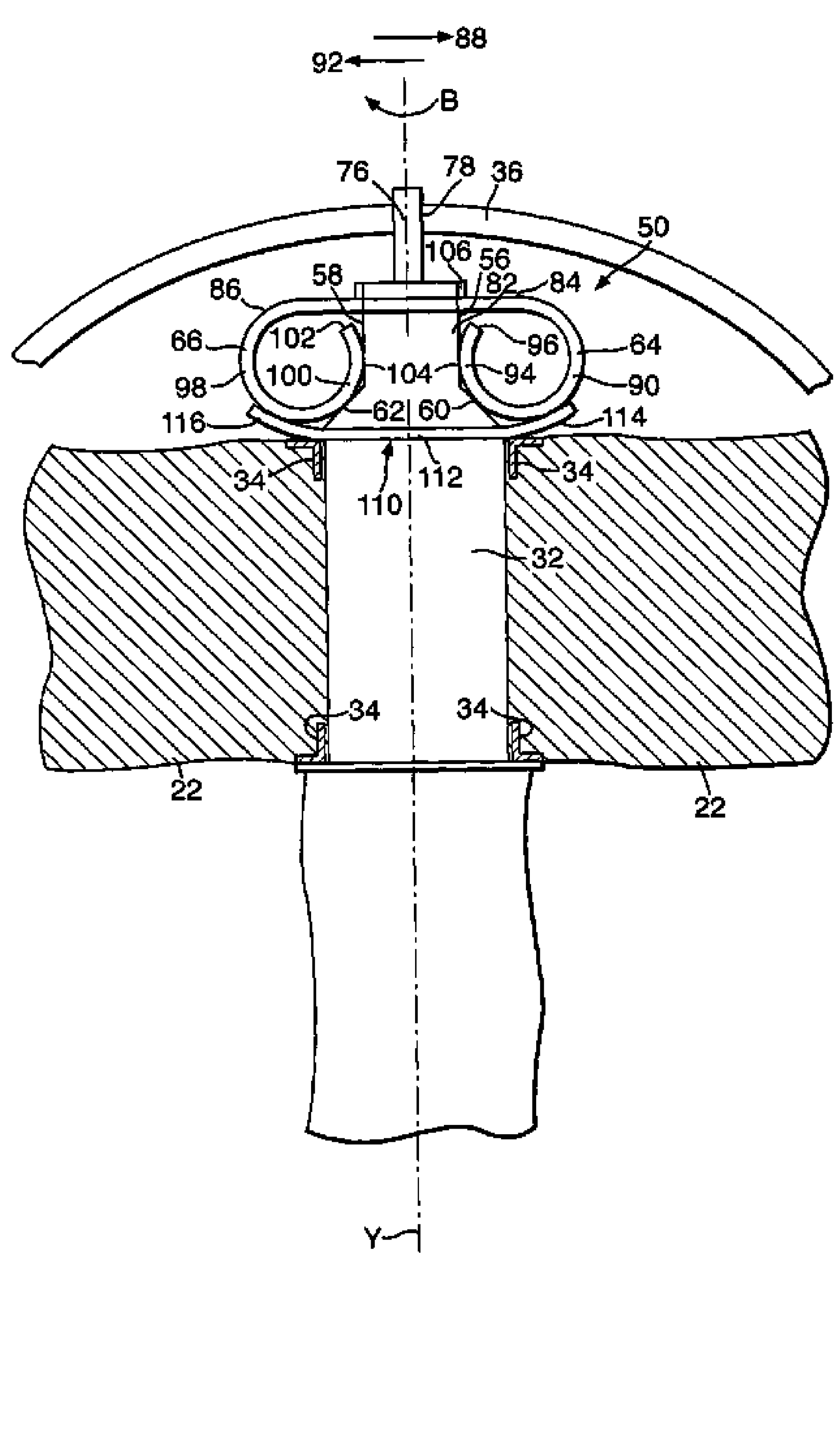
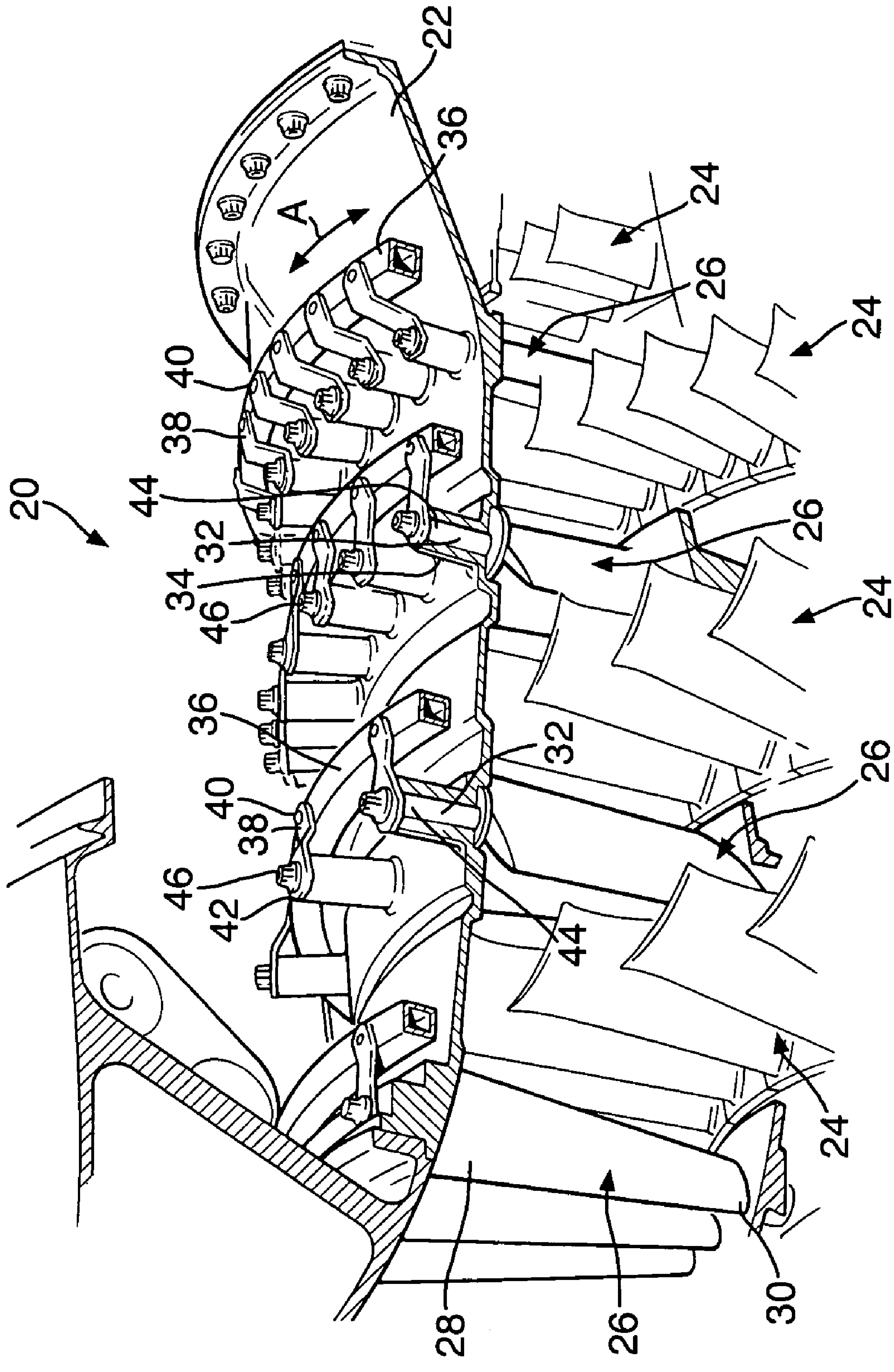


Fig.1.



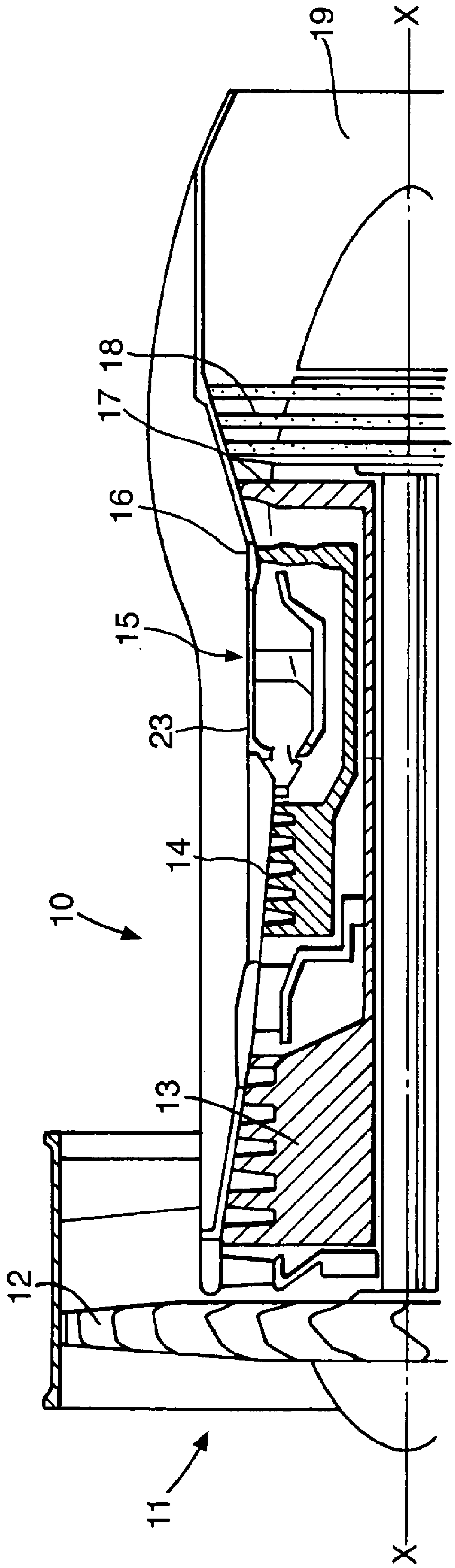


Fig.2.

Fig.3.

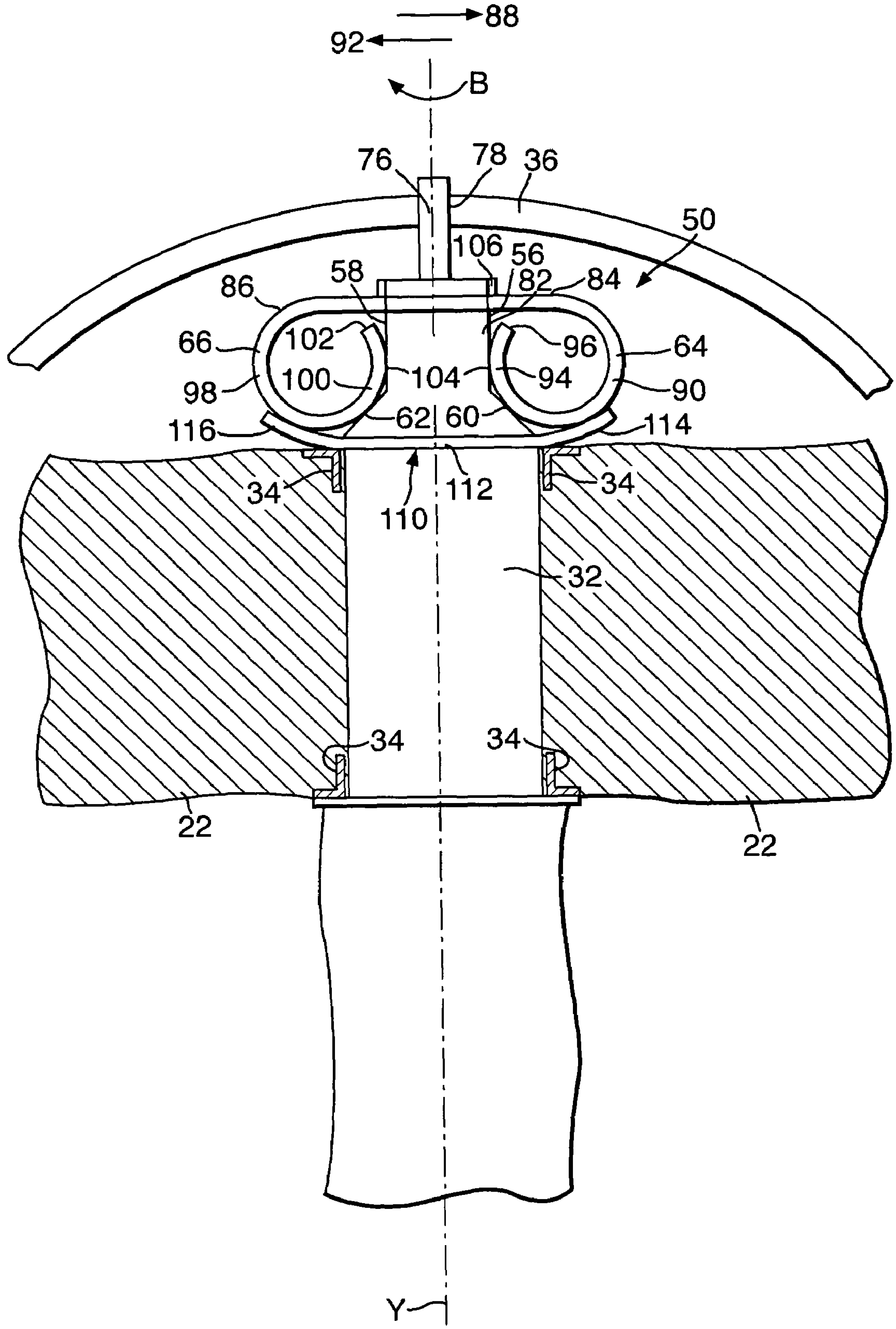

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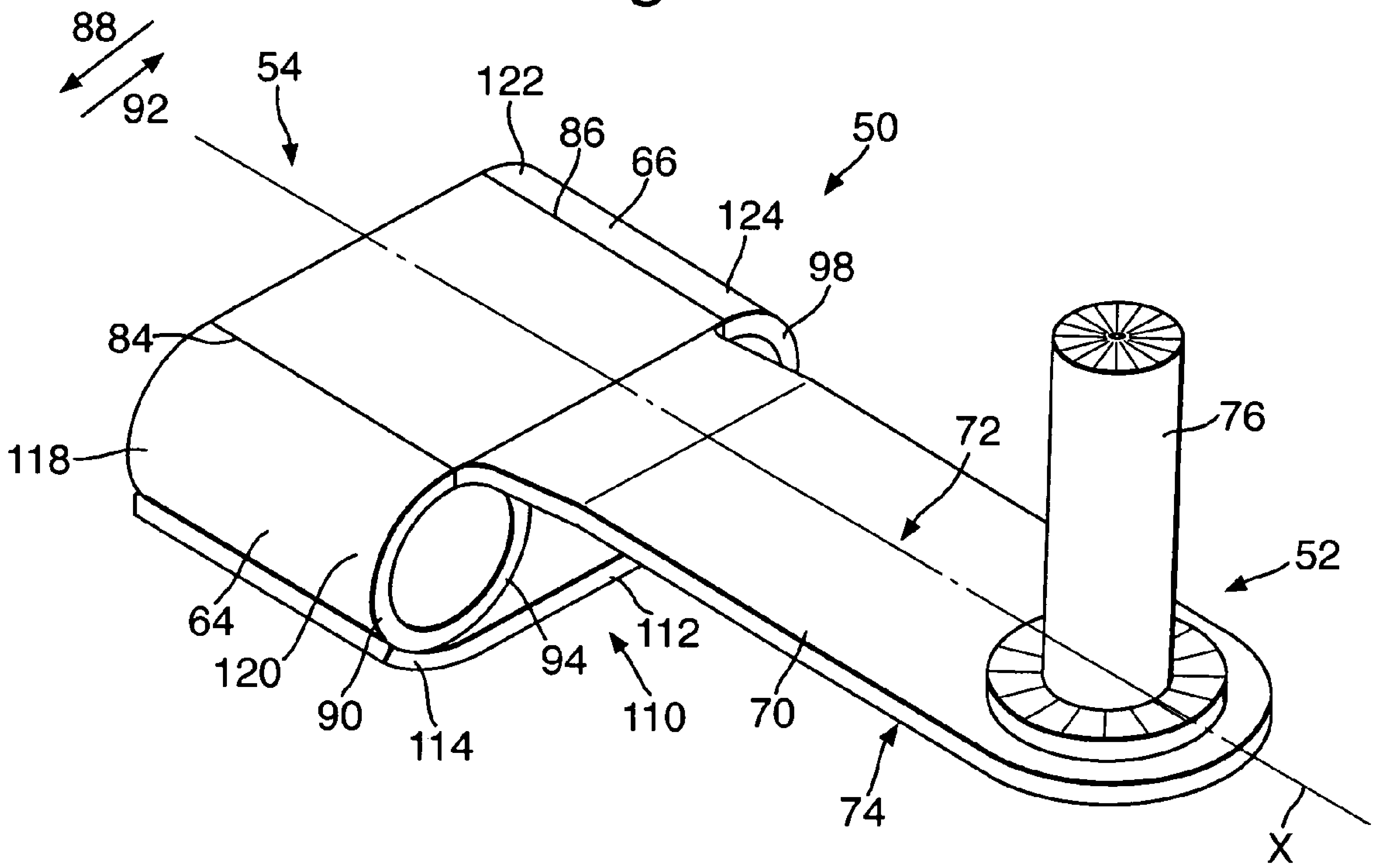
Fig.4.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VARIABLE STATOR VANE ACTUATING LEVERS

FIELD OF THE INVENTION

Embodiments of the present invention relate to a variable stator vane actuating lever for use in a gas turbine engine and/or a system for positioning variable stator vanes.

BACKGROUND OF INVENTION

FIG. **1** shows a typical compressor **20** of a gas turbine engine. The compressor **20** comprises a casing **22** and a plurality of sets of rotor blades **24** mounted for rotation about a longitudinal axis of the compressor **20**. Upstream of each set of rotor blades **24** is mounted a set of variable stator vanes **26**, each having a first end **28** and a second end **30** rotatably mounted in the casing **22**. The first end **28** includes a stator vane spindle **32** mounted for rotation in a bush **34** in the casing **22**.

A stator vane actuator ring **36** extends circumferentially around the outside of the casing **22** adjacent to each set of stator vanes **26**. Each stator vane spindle **32** is mechanically connected to an adjacent actuator ring **36** by a variable stator vane actuating lever **38**. Each actuating lever **38** has a first end **40** pivotally connected to an adjacent actuator ring **36** and a second end **42** immovably attached to an upper end **44** of each vane spindle **32** by a bolt **46** or stud and nut.

Each actuator ring **36** is circumferentially rotatable in either direction about the longitudinal axis of the compressor **20**, as indicated by arrow A. This is conventionally achieved by use of an actuating system (not shown). The actuating system may be hydraulic, pneumatic or electric, etc. When an actuator ring **36** is caused to rotate, its rotational movement is transmitted by each of the plurality of actuating levers **38** to the respective stator vane spindles **32** of a set of variable stator vanes **26** causing the spindles **32** to rotate in their respective bushes **34**. Rotation of the spindles **32** in turn causes simultaneous rotation of the corresponding set of variable stator vanes **26**.

Variable stator vanes are used in gas turbine engines to control airflow through a multi-stage compressor. In the event of breakdown of airflow through the compressor, a condition known as ‘surge’ can occur in which high pressure air is expelled from the combustor into the compressor stages, thereby causing a sudden reversal of the airflow through the compressor and a resultant sudden loss of engine thrust.

Under surge conditions, the reversed airflow can impart a significant shock load onto the variable stator vanes, inducing rotational vibration. Existing variable stator vane actuating levers transmit most of this load to the actuating system, which may cause damage. It would be desirable to reduce the likelihood of such damage occurring in such situations and/or similar situations.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention, there is provided a variable stator vane actuating lever for use in a gas turbine engine, the lever comprising a first end for pivotal connection to a stator vane actuator and a second end for abutting a stator vane spindle having a diameter and flat portions, the second end having resilient members for abutting the flat portions of the vane spindle at diametrically opposite locations.

The actuating lever may have first and second resilient members, the first resilient member extending in a first direction and returning in a second direction to abut the vane spindle at a first flat portion and the second resilient member extending in the second direction and returning in the first direction to abut the vane spindle at a second flat portion. The first and second resilient members may each extend from the second end of the actuating lever and curve through first and second curved portions and terminate at an unconstrained end.

The first and second resilient members may have opposing surfaces, which may define therebetween a gap for receiving the vane spindle. The opposing surfaces may abut, in use, the flat portions of the vane spindle. The opposing surfaces may be curved and may each abut, in use, the vane spindle at two locations.

A pin may be provided at the first end of the actuating lever to provide for pivotal connection of the actuating lever to the stator vane actuator.

According to a second aspect of the present invention there is provided a stator vane assembly comprising an actuating lever according to any of the preceding four paragraphs and a stator vane spindle, wherein the stator vane spindle has a longitudinal axis and the resilient members are symmetric about the longitudinal axis.

According to a third aspect of the present invention, there is provided a stator vane assembly comprising an actuating lever according to any of the preceding five paragraphs, a stator vane spindle having a longitudinal axis, and a constraint locatable on the vane spindle to abut the resilient members and constrain movement thereof.

The constraint may include first and second curved portions for abutting respectively the first and second resilient members and may also be symmetric about the longitudinal axis of the vane spindle.

A fastener may be provided to secure the second end of the actuating lever to the vane spindle.

According to a fourth aspect of the present invention, there is provided a variable stator vane actuating lever for use in a gas turbine engine, the lever comprising; a first end for pivotal connection to a stator vane actuator, and a second end including:

a first resilient member extending in a first direction and returning in a second direction to form a first curved portion for abutting a stator vane spindle, and;

a second resilient member extending in the second direction and returning in the first direction to form a second curved portion for abutting the stator vane spindle.

The first and second resilient members may have opposing surfaces for abutting the stator vane spindle.

According to a fifth aspect of the present invention, there is provided a system for positioning variable stator vanes comprising a variable stator vane actuator, a stator vane spindle associated with each stator vane having a diameter and flat portions, and a plurality of variable stator vane actuating levers each having a first end for pivotal connection to the actuator and a second end having resilient members for abutting the flat portions of a vane spindle and providing for relative rotational movement between the vane spindle and the actuating lever.

The stator vane spindle may have a longitudinal axis and the flat portions may be symmetric about the longitudinal axis. The flat portions may include first and second flattened surfaces substantially parallel to the longitudinal axis of the vane spindle. The flat portions may also include third and fourth flattened surfaces inclined with respect to the longitudinal axis of the vane spindle.

The present invention also provides a gas turbine engine including a system for positioning variable stator vanes as defined in any of the two preceding paragraphs.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment of the present invention will now be described by way of example only with reference to the accompany drawings, in which:

FIG. **1** is a diagrammatic perspective view of a compressor for a gas turbine engine;

FIG. **2** is a diagrammatic cross-sectional view of a part of a gas turbine engine;

FIG. **3** is a diagrammatic cross-sectional view of a stator vane actuating assembly including a variable stator vane actuating lever according to the present invention; and

FIG. **4** is a diagrammatic perspective view of the variable stator vane actuating lever of FIG. **3**.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **2**, a gas turbine engine is generally indicated at **10** and comprises, in axial flow series, an air intake **11**, a propulsive fan **12**, an intermediate pressure compressor **13**, a high pressure compressor **14**, combustion equipment **15**, a high pressure turbine **16**, an intermediate pressure turbine **17**, a low pressure turbine **18** and an exhaust nozzle **19**.

The gas turbine engine **10** works in a conventional manner so that air entering the intake **11** is accelerated by the fan **12** which produces two air flows: a first air flow into the intermediate pressure compressor **13** and a second air flow which provides propulsive thrust. The intermediate pressure compressor **13** compresses the air flow directed into it before delivering that air to the high pressure compressor **14** where further compression takes place.

The compressed air exhausted from the high pressure compressor **14** is directed into the combustion equipment **15** where it is mixed with fuel and the mixture combusted. The resultant hot combustion products then expand through, and thereby drive, the high, intermediate and low pressure turbines **16**, **17** and **18** before being exhausted through the nozzle **19** to provide additional propulsive thrust. The high, intermediate and low pressure turbines **16**, **17** and **18** respectively drive the high and intermediate pressure compressors **14** and **13**, and the fan **12** by suitable interconnecting shafts.

FIGS. **3** and **4** show a variable stator vane actuating assembly for a gas turbine engine comprising a stator vane spindle **32**, a constraint **110**, and a variable stator vane actuating lever **50**. The actuating lever **50** comprises generally a first end **52** for pivotal connection to a stator vane actuator such as an actuator ring **36** and a second end **54** for abutting a stator vane spindle **32**. The stator vane spindle **32** has a diameter and flat portions such as first, second, third and fourth flattened surfaces **56**, **58**, **60**, **62**. The second end **54** has first and second resilient members **64**, **66** for abutting the flat portions **56**, **58**, **60**, **62** of the vane spindle **32** at diametrically opposite locations.

In more detail, the actuating lever **50** is formed from a titanium metal strip having upper and lower surfaces **72**, **74** and a longitudinal axis X extending between the first and second ends **52**, **54**. At the first end **52** of the lever **50** on the upper surface **72** is provided a pin **76** locatable in a bush **78** of the actuator ring **36** to provide for the pivotal connection of the first end **52** of the lever **50** to the actuator ring **36**.

As best seen in FIG. **3**, the vane spindle **32** is rotatably mounted about its longitudinal axis Y in bushes **34** in the compressor casing **22** and has an upper portion **82** which extends beyond the casing **22**. At the upper portion **82**, the vane spindle **32** has first and second flattened surfaces **56**, **58** which are substantially parallel to each other and the longitudinal axis Y of the spindle **32** and located on opposite sides of the spindle **32**. The upper portion **82** also has third and fourth flattened surfaces **60**, **62** which are inclined with respect to the longitudinal axis Y of the spindle and again located on opposite sides thereof. The first and third surfaces **56**, **60** are located adjacent each other, and meet, on one side of the vane spindle **32**. The second and fourth flattened surfaces **58**, **62** are located adjacent each other, and meet, on the opposite side of the spindle **32**. The first and third flattened surfaces **56**, **60** and the second and fourth flattened surfaces **58**, **62** are symmetrically positioned, with reflectional symmetry about the longitudinal axis Y, and together form a 'cottage roof'.

At the second end **54** of the actuating lever **50**, the first and second resilient members **64**, **66** extend from, and are integrally formed with, the metal strip **70** providing the first and second resilient members **64**, **66** with a respective constrained end **84**, **86**. The first resilient member **64** extends from the actuating lever **50** in a first direction **88** perpendicular to a vertical plane through the longitudinal axis X of the actuating lever **50**, downwardly curves through a first curved portion **90** and upwardly curves through a second curved portion **94** and terminates at an unconstrained free end **96**. In a similar manner, the second resilient member **66** extends from the actuating lever **50** initially in a second direction **92** which is opposite to the first direction **88** and again perpendicular to a vertical plane through the longitudinal axis X of the actuating lever **50**, downwardly curves through a first curved portion **98** and upwardly curves through a second curved portion **100** and terminates at an unconstrained free end **102**.

The first and second resilient members **64**, **66** are symmetric about the vertical plane through the longitudinal axis X of the actuating lever **50** and extend a short distance from the second end **54** towards the first end **52** parallel to the longitudinal axis X, such that the first and second resilient members **64**, **66** are substantially tubular. This distance corresponds substantially to the width of the corresponding flattened surfaces **56**, **58**, **60**, **62** of the vane spindle **32**. The first resilient member **64** has front and rear portions **118**, **120** and the second resilient member **66** front and rear portions **122**, **124**.

The second curved portions **94**, **100** of the first and second resilient members **64**, **66** have opposing surfaces **104** which define a gap for receiving the upper portion **82** of the vane spindle **32**. The curved opposing surfaces **104** of the first and second resilient members **64**, **66** each abut the first and second flattened surfaces **56**, **58**, and also the third and fourth flattened surfaces **60**, **62**, at diametrically opposite locations. Thus, each of the resilient members **64**, **66** abuts the upper portion **82** of the vane spindle **32** at two diametrically opposite locations. The diameter of the vane spindle **32** extends at right angles to the longitudinal axis Y of the vane spindle **32**.

The second end **54** of the actuating lever **50** is secured to the upper end **44** of the vane spindle **32** by means of a threaded fastener **106**, such as a nut, or stud and nut.

A constraint **110** is optionally located on the vane spindle **32** on the upper portion **82** adjacent the compressor casing **22**. The constraint **110** includes a substantially planar portion **112** and first and second curved portions **114**, **116** which abut respectively the first and second resilient members **64**, **66** to constrain movement thereof. The constraint **110** is symmetric about the longitudinal axis Y of the vane spindle **32**.

Under normal engine operating conditions, the first and second resilient members **64**, **66** are sufficiently stiff to transmit steady movement of the actuator ring **36** via the actuating lever **50** to the vane spindle **32**, without significant relative movement occurring between the actuating lever **50** and the vane spindle **32**.

Under surge conditions, the actuating lever **50** acts as a shock absorber. When a shock load is exerted on the stator vane **26** under surge conditions, it will vibrate by rotating rapidly in one direction, then in the other direction. This will cause the vane spindle **32** to vibrate in the same manner. When the vane spindle **32** rotationally vibrates in this way, the resilient members **64**, **66** of the actuating lever **50** deform to allow relative movement between the vane spindle **32** and the actuating lever **50**. For example, when the vane spindle **32** rotates in the direction of arrow B shown in FIG. **3**, the rear portion **120** and the front portion **122** of the first and second resilient members **64**, **66** are compressed outwardly due to contact with the flattened surfaces **56**, **58**, **60**, **62** of the spindle **32**, whilst the front portion **118** and the rear portion **124** of the first and second resilient members **64**, **66** expand inwardly. When the direction of rotation of the vane spindle **32** reverses, the front portion **118** and the rear portion **124** of the first and second resilient members **64**, **66** are compressed outwardly whereas the rear portion **120** and the front portion **122** of the first and second resilient members **64**, **66** expand inwardly. This alternate deformation of the resilient members **64**, **66** by compression and expansion continues until the rotational vibration of the vane spindle **32** ceases. The curved portions **114**, **116** of the constraint **110**, when present, constrain movement of, and provide additional stiffness to, the first and second resilient members **64**, **66**. Due to the symmetry of the constraint **110**, it tends to apply substantially equal restraining forces to both the first and second resilient members **64**, **66**.

After the rotational vibration of the stator vane **26**, and hence the vane spindle **32**, has ceased, the inherent stiffness of the first and second resilient members **64**, **66** causes them to return to their undeformed state to abut the flattened surfaces **56**, **58**, **60**, **62** of the vane spindle **32**. This ensures proper location of the actuating lever **50** on the vane spindle **32** once the vibration has subsided.

The large contact area between the first and second resilient members **64**, **66** and the respective flattened surfaces **56**, **58**, **60**, **62** of the vane spindle **32** ensures there is an even load distribution and also provides for improved location of the actuating lever **50** on the vane spindle **32**.

By deforming in the manner described, the first and second resilient members **64**, **66** enable some of the shock load experienced under surge conditions to be absorbed by allowing relative movement between the vane spindle **32** and the actuating lever **50**. This reduces the load transmitted to the actuator ring **36** by the actuating lever **50**, thereby reducing the likelihood of damage to these components and increasing the probability of the surge being recoverable.

Various modifications may be made without departing from the scope of the present invention as defined in the accompanying claims. For example, whilst the actuating lever has been described for use in a compressor of a gas turbine engine, it could alternatively or additionally be used in the turbine. The resilient members **64**, **66** may be of a different configuration. The constraint **110** may be replaced by a shim or omitted. The actuating lever **50** may be manufactured from materials other than titanium, such as stainless steel, another metal or a composite material.

Whilst endeavouring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance, it should be understood that the Applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings, whether or not particular emphasis has been placed thereon.

I claim:

1. A variable stator vane assembly for use in a gas turbine engine comprising an actuating lever and a stator vane spindle having a longitudinal axis, a diameter around the longitudinal axis and flat portions at diametrically opposite locations, the lever comprising a first end for pivotal connection to a stator vane actuator and a second end having resilient members abutting the flat portions of the stator vane spindle, wherein a fastener is provided to secure the second end of the actuating lever to the vane spindle.

2. A variable stator vane assembly according to claim **1**, wherein the actuating lever has first and second resilient members, wherein the first resilient member extends in a first direction and returns in a second direction to abut the vane spindle at a first flat portion and the second resilient member extends in the second direction and returns in the first direction to abut the vane spindle at a second flat portion.

3. A variable stator vane assembly according to claim **2**, wherein the first and second resilient members each extend from the second end of the actuating lever and curve through first and second curved portions and terminate at a respective first and second unconstrained end.

4. A variable stator vane assembly according to claim **2**, wherein the first and second resilient members have opposing surfaces.

5. A variable stator vane assembly according to claim **4**, wherein the opposing surfaces define therebetween a gap for receiving the vane spindle.

6. A variable stator vane assembly according to claim **4**, wherein the opposing surfaces abut, in use, the flat portions of the vane spindle.

7. A variable stator vane assembly according to claim **4**, wherein the opposing surfaces are curved and each abuts, in use, the vane spindle at two locations.

8. A variable stator vane assembly according to claim **1**, wherein a pin is provided at the first end of the actuating lever to provide for pivotal connection of the actuating lever to the stator vane actuator.

9. A variable stator vane assembly according to claim **1**, wherein and the resilient members are symmetric about the longitudinal axis.

10. A variable stator vane assembly according to claim **1**, further comprising a constraint locatable on the stator vane spindle to abut the resilient members and constrain movement of the resilient members.

11. A variable stator vane assembly according to claim **10**, wherein the constraint includes first and second curved portions for abutting respectively the first and second resilient members.

12. A variable stator vane assembly according to claim **10**, wherein the constraint is symmetric about the longitudinal axis of the vane spindle.

13. A system for positioning variable stator vanes comprising a variable stator vane actuator, a stator vane spindle associated with each stator vane having a diameter and flat portions at diametrically opposite locations on the outermost periphery of the vane spindle, and a plurality of variable stator vane actuating levers each having a first end for pivotal connection to the actuator and a second end having resilient members which abut the flat portions of a vane spindle and provide for relative rolational movement between the vane spindle and the actuating lever.

14. A system according to claim **13**, wherein the stator vane spindle has a longitudinal axis and the flat portions are symmetric about the longitudinal axis.

15. A system according to claim **14**, wherein the flat portions include first and second flattened surfaces substantially parallel to the longitudinal axis of the vane spindle.

16. A system according to claim **14**, wherein the flat portions include third and fourth flattened surfaces inclined with respect to the longitudinal axis of the vane spindle.

17. A system according to claim **13**, wherein each of the plurality of variable stator vane actuating levers comprises a first end for pivotal connection to a stator vane actuator and a second end having resilient members abutting the flat portions of the stator vane spindle.

18. A gas turbine engine including a system for positioning variable stator vanes as defined in claim **13**.

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